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Implementation of Lifetime Maximization Strategies for Wireless Sensor

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Abstract **- One issue in wireless sensor networks is achieving efficient operation because of the limited available power. Energy efficient transmission is of vital importance in the design of wireless sensor networks (WSN). Balancing energy consumption and prolonging network lifetime is the main aim of this paper. Energy efficiency is a primary concern in the design of algorithms and protocols for wireless sensor networks. In the research field of WSNs how to reduce the energy consumption of WSN so that the lifetime of WSN can be prolonged is one of the hottest spots. We focus on different techniques to reduce the consumption of the limited energy budget of sensor nodes. After having identified the reasons of energy waste in WSNs, we have implemented the strategies to enhance the lifetime of wireless sensor network. We have implemented four existing protocols namely, Directed Diffusion protocol, LEACH protocol, LEACH with TREE and TREEPSI protocols and proposed two protocols named as Novel1 protocol and Novel2 protocol which are implemented in NS2. We have compared LEACH protocol with Novel1 protocol and TREEPSI protocol with Novel2 protocol to show that proposed protocols improves the performance of wireless sensor network. Experimental results showed that the proposed protocols are more efficient than existing protocols through which lifetime of wireless sensor network is enhanced.**

Keywords **- energy consumption, energy efficiency, lifetime, wireless sensor networks.**

I. INTRODUCTION

A WSN consists of hundreds to thousands of sensor nodes that have the ability to communicate among themselves using radio antenna. A WSN node mainly consists of four main parts: Processing unit, Sensor, Transceiver, Energy Source Unit which is shown in figure 1. These nodes are usually small in size with limited processing power, limited memory and limited energy source [1]. In WSNs, the sensor devices are very constrained in terms of battery power. The lifetime of an individual sensor node is equal to the lifetime of the battery [11].

Sensor nodes in WSNs have non- rechargeable batteries. At the same time, it is not easy to replace batteries because WSNs are deployed generally in inhospitable environments like forests, sea and battle-fields. The base station (BS) is a special node in a WSN which connects the sensor nodes to the outside world. The BS is equipped with a battery with sufficient capacity and it is not supposed to fail due power shortage [11].

Although, the BS has sufficient battery power, the nodes which are in the proximity of it have limited battery power [11]. The information generated by other nodes will ship to the BS via the nodes which are nearer to it. The only way to make the WSN alive for longer time is to use the battery power efficiently [3]. In this paper we have implemented two novel protocols which enhances the lifetime of wireless sensor network.

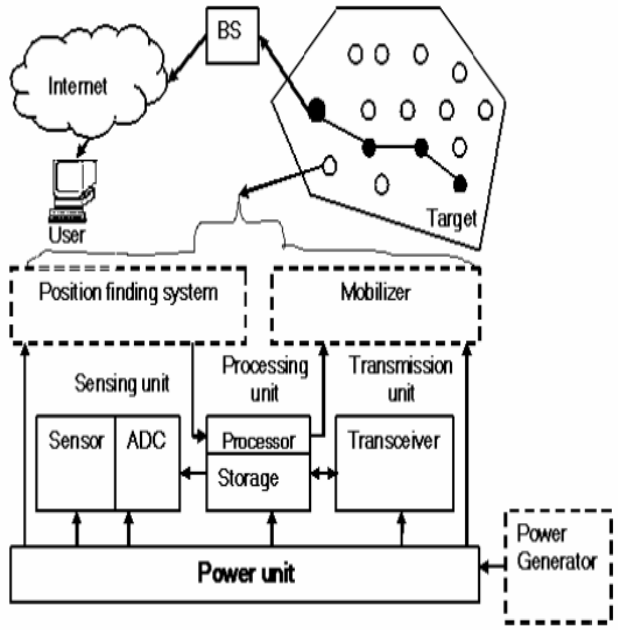

Fig.1. WSN node

II. REASONS OF POTENTIAL ENERGY WASTE IN A WSN

In WSNs, sensors dissipate energy while sensing, processing, transmitting or receiving data to fulfill the mission required by the application. With regard to communication, there is also a great amount of energy wasted in states that are useless from the application point of view, such as [19]:

1. Collision: when a node receives more than one packet at the same time, these packets collide. All packets that cause the collision have to be discarded and the retransmission of these packets is required.
2. Overhearing: when a sender transmits a packet, all nodes in its transmission range receive this packet even if they are not the intended destination. Thus, energy is wasted when a node receives packets that are destined to other nodes.
3. Control packet overhead: a minimal number of control packets should be used to enable data transmissions.
4. Idle listening: is one of the major sources of energy dissipation. It happens when a node is listening to an idle channel in order to receive possible traffic.
5. Interference: each node located between transmission range and interference range receives a packet but cannot decode it.

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III. STRATEGIES TO MAXIMIZE LIFETIME OF WSN

A. Low Energy Adaptive Clustering Hierarchy (LEACH)

LEACH is representative cluster-based of routing protocols. It is also the first proposed in wireless sensor network and can reduce power consumption on avoiding the communication directly between sink and sensor nodes. In a sensor field, sensor node senses data and sends data to the sink that called "round". LEACH is a cluster-based energy efficient routing protocol, which reduce the number of transmissions towards to the BS. In other words, it reduces network traffic and the contention for the channel. LEACH has motivated the design of several other protocols which try to improve upon the CH selection process. The Protocols basically differ depending on the application and network architecture used in their design. The main objectives of LEACH are:

1. Extension of the network lifetime
2. Reduced energy consumption by each network sensor node
3. Use of data aggregation to reduce the number of communication messages

To achieve these objectives, LEACH adopts a hierarchical approach to organize the network into a set of clusters. Each cluster is managed by a selected cluster head. The cluster head assumes the responsibility to carry out multiple tasks. The first task consists of periodic collection of data from the members of the cluster. Upon gathering the data, the cluster head aggregates it in an effort to remove redundancy among correlated values. The second main task of a cluster head is to transmit the aggregated data directly to the base station. The transmission of the aggregated data is achieved over a single hop.

The network model used by LEACH is depicted in Figure 2. The third main task of the cluster head is to create a TDMA-based schedule whereby each node of the cluster is assigned a time slot that it can use for transmission. The cluster head advertises the schedule to its cluster members through broadcasting. The basic operations of LEACH are organized in two distinct phases. These phases are illustrated in Figure 3

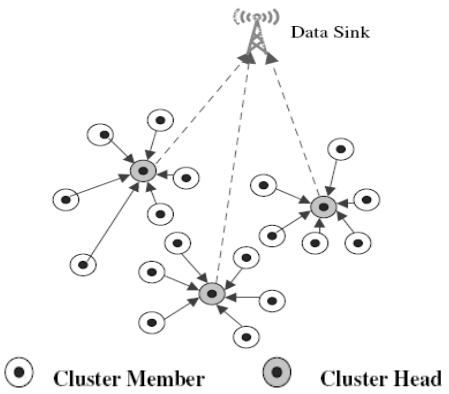

Fig.2. LEACH network model

The first phase, the setup phase, consists of two steps, cluster-head selection and cluster formation. The second phase, the steady-state phase, focuses on data collection, aggregation, and delivery to the base station. The duration of the setup is assumed to be relatively shorter than the steady-state phase to minimize the protocol overhead.

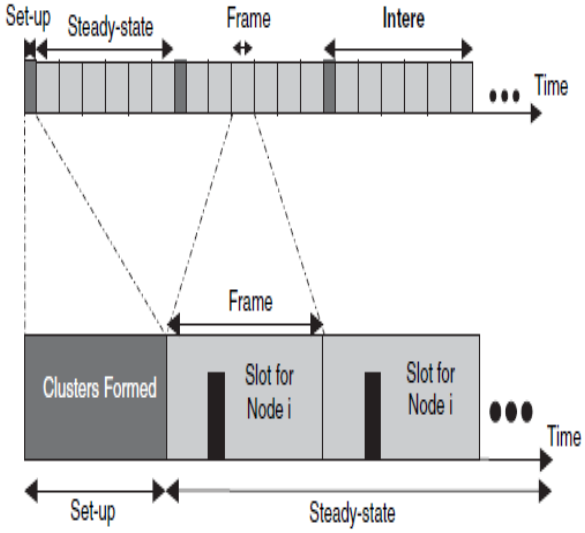

Fig.3. LEACH phases

B. LEACH with TREE Protocol

LEACH protocol suffers from many drawbacks like CH selection is random, that does not take into account energy consumption, it can't cover a large area, CHs are not uniformly distributed; where CHs can be located at the edges of the cluster and CHs direct communicate with BS. If distance between new node and Cluster head is long then new node will require more energy to transmit data to the Cluster Head. If new node is not in the range of CH and out of the range of cluster formation range then there are two possibilities to transmit data from new node to base station. First possibility is: again to form the clusters using LEACH protocol of all nodes including existing nodes and new node. But this will consume more energy to reconstruct the clusters of the entire node in the network.

When the distance between cluster node to CH is less than d0, the free space (fs) channel model is used (d2 power loss). Therefore the energy dissipates by the radio to transmit l bit message to the distance of d calculates as shown in formula.

$$E_{TX}(l, d) = l\, Eelec + l\, \epsilon_{mp} d^2 \qquad d<d0$$

In this formula l is number of bits, Eelec is the energy dissipation to run the radio electronics and the εmp energy dissipation values to run the amplifier signal. When the distance between cluster node to CH is greater than d0, the free space (fs) channel model is used (d4 power loss). Therefore the energy dissipates by the radio to transmit l bit message to the distance of d calculates as shown in formula.

$$E_{TX}(l, d) = l\, Eelec + l\, \epsilon_{mp} d^4 \qquad d >= d0$$

Second possibility is to form LEACH with TREE Protocol, in this protocol the network is divided into two

levels

• Tree Level.
• Cluster level.

In Tree level, new node forms the tree with nearest node which is present in the range of cluster head. RN is always in the range of CH. In cluster level, cluster is form using cluster protocol like LEACH protocol. In cluster level, cluster is form using LEACH protocol. Figure 4 shows LEACH with TREE protocol.

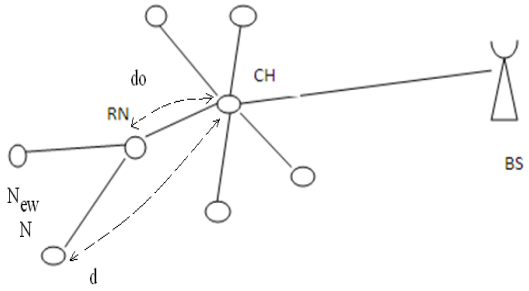

Fig.4. LEACH with TREE Protocol

In LEACH with TREE protocol, new node first transmits data to the root node and then root node will transmit the data to the Cluster head. CH receives all data from all non CH nodes in the TDMA schedule and then transmits it to the BS. In this protocol the distance between node and CH is reduced, energy consumption is automatically get reduced which will improve the lifetime of WSN.

C. Novel1 Protocol

In novel1 protocol, cluster contains: Cluster head (CH) which is responsible for receiving data from the cluster members, perform data aggregation process over the received data and then to the BS, Associate CH the node that will become a CH of the cluster in case of CH energy below from average energy, cluster nodes gathering data from environment and send it to the CH. In case of LEACH the CH will die earlier than the other nodes in the cluster because of its operation of receiving, sending and overhearing.

When the CH die, the cluster will become useless because the data gathered by cluster nodes will never reach the base station because of sensor node have resource constraint in the network. Therefore selection of cluster head become important, cluster head is selected based on the energy and that sensor node is selected as a CH (cluster-head). While processing of Cluster head node the energy become reduce, so if the energy of CH is becomes below to the non cluster head nodes energies means next round should be processed.

In the next round, the Associate cluster-head should be made as a lead while selection of cluster head for the first round, so no need to select the cluster-head for next round. novel1 reclustering, reduce the overhead of clustering process, reduce the load over cluster head, and reduce the energy consumption within cluster in large-scale and dense sensor networks with the help of novel approach consumes limited energy to send the data. Also avoiding cluster set up phase and cluster steady phase. Novel1 approach works in two phases namely: Cluster set-up phase and cluster steady phase same as a LEACH protocol.

Novel1 approach work into rounds. Each round begins with a set-up (clustering) phase when clusters are structured, followed by a cluster steady phase, the CH is always on receiving data from cluster members, aggregate these data and then send it to the BS that might be located far away from it.

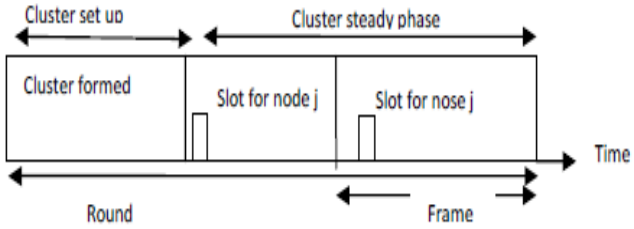

Fig.5. Novel1 operation

- ***Cluster Set-up phase***

In set-up phase, the cluster head is selected and then it forms a group. So after some time the corresponding Cluster head energy to be reduced and to rotate the cluster head selection process. In the selection of cluster head each node decides whether to turn into cluster head or not average residual energy. Some nodes with more residual energy turn into cluster heads and send cluster head information to inform other nodes. The other nodes with less residual energy turn into common nodes, and send information about joining cluster to a cluster head.

- ***Cluster steady phase***

In which clusters are created and the corresponding cluster head is selected. After the cluster head receives the data it can be aggregated and the data can be transmitted to the base station. During the set-up phase each sensor node sends information about its current location to the base station. In order to determining good clusters, the base station needs to ensure that the energy load is evenly distributed among all the sensor nodes. Sensor nodes sends their energy level to the base station, The base station computes average node energy, and determines which nodes have energy high or below this average, some nodes having higher energy compare to average energy choose as cluster head for current round. Then broadcasts an advertisement message to the rest of the nodes. For this "CH advertisement" phase, the CHs use a CSMA MAC protocol, and all CHs transmit their advertisement using the same transmit energy. The non CH nodes must keep their receiver on during the phase of set up to hear the advertisements of all the CH nodes. After this phase is complete, each non-CH node decides the cluster to which it will belong for this round. This decision is based on the received signal strength of the advertisement. After each node has decided to which cluster it belongs, it must inform the CH node that it will be a member of the cluster. Each node transmits this information back to the CH again using a CSMA MAC protocol. During this phase, all CH nodes must keep their receivers on. The CH node receives all the messages for nodes that would like to be included in the cluster. Based on the number of nodes in the cluster,

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the CH node creates a TDMA schedule telling each node when it can transmit. This schedule is broadcast back to the nodes in the cluster. Once the clusters are created and the TDMA schedule is fixed, data transmission can begin. Nodes send data during their allocated transmission time to the CH. This transmission uses a minimal amount of energy.

The radio of each non-CH nodes can be turned off until the node's allocated transmission time, to minimizing energy dissipation in these nodes. The CH must keep its receiver on to receive all the data from the nodes in the cluster. When all the data has been received, the CH performs data aggregation. This aggregated data is sent to the BS. This transmission takes high energy because BS is far away from CH. After certain period Cluster-head node energy become reduced, because of its operation of receiving, sending and overhearing processing so if the energy of CH is becomes below the non-cluster-head nodes energies means next round should to be processed. In the next round, the Associate cluster-head should be made as a lead while selection of cluster-head for the first round, then all data would be transferred to associate CH. And associate cluster head take place as a CH for that round so no need to select the cluster-head for next round.

D. TREEPSI Protocol

The energy efficiency in tree-based protocol like TREEPSI is better than cluster based and chain-based protocol. If some sensor nodes send data to the sink, this information of nodes will make a detour. Thus, that will cause more power dissipation in data gathering. This situation is happened as building the binary tree paths, especially when the sensor field is large and the numbers of sensor nodes are large. In TREEPSI protocol we have considered the wireless sensor network consist of vast no of nodes. We then divide the network into number of clusters and each cluster is represented by cluster head.

The data collected by cluster nodes are passed to the cluster head, cluster head will aggregate the data and passed to the base station if the cluster head is nearest to the BS. If the cluster head is farthest from the base station then this aggregated data is passed to cluster head of another cluster which is nearest to the BS. In this way the data is passed from CH to CH to reduce energy consumption of cluster head which is farthest from the BS and finally transmitted to the BS using nearest CH. All the cluster heads are connected in Tree pattern and lastly connected to the BS which is shown in figure 6. Because energy required to transmit data from nearest cluster head to BS will be less. In this way our implemented TREEPSI protocol will reduce energy consumption and enhance the lifetime of WSN.

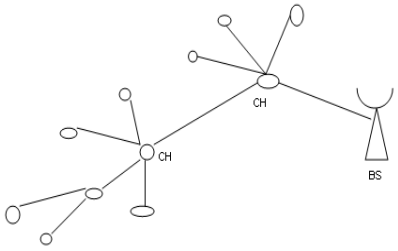

Fig.6. TREEPSI Protocol

E. Novel2 Protocol

In TREEPSI protocol the data collected from cluster member is transmitted from cluster head to cluster head in the form of TREE and finally root of the TREE or the cluster head nearest to the base station will transmit the aggregated data to the base station. As last cluster head collect the data from all cluster head in the network the energy of this CH get reduced and the cluster head will get die. This is one of the drawback of TREEPSI protocol. This drawback is recovered in our proposed novel2 protocol. In our implemented novel2 protocol there is a concept of associate CH. This associate CH will takes place as a cluster head and then all data would be transferred to associate CH and associate CH will send all the data to the base station which is shown in figure 7. In this way the concept of associate cluster head will improve the performance of wireless sensor network by reducing energy consumption of root node in TREEPSI protocol.

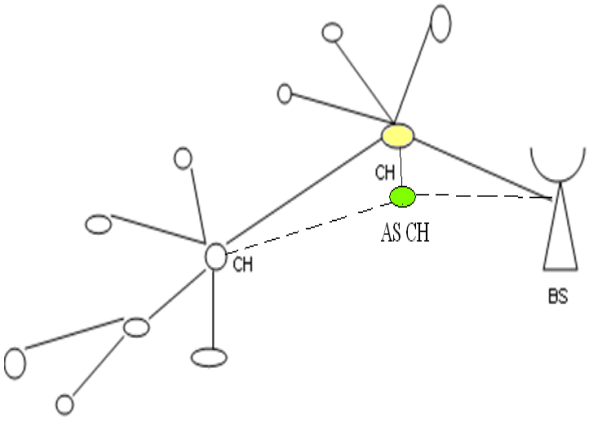

Fig.7. Novel2 Protocol

IV. EXPERIMENTAL RESULTS

F. Simulation Setup

The simulation is carried out in NS-2 simulator installed on Linux machine. The experimental set up consists of 11 wireless nodes. All the nodes use AODV as a routing protocol within the area of 951m x100m. AODV protocol is a suitable approach for wireless networks due to low message overhead. The simulation is run for 50 seconds. The simulation statistics shown in table I is for Direct Diffusion, LEACH protocol, LEACH with TREE Protocol and Novel1 Protocol and the simulation statistics shown in table II is for TREEPSI and Novel2 Protocol.

Table I: Simulation Statistics for DIRECT DIFFUSION, LEACH, LEACH with TREE and NOVEL1 Protocol.

Parameters	Values
Simulation Area	951m * 100m
Number of Nodes	11
Node initial Energy	10 Joule
Packet Size	512 bytes

Traffic Type	CBR (UDP)
The propagation Model	TwoRayGround
Simulation Time	50 Seconds

TableII: Simulation Statistics for TREEPSI and NOVEL2 Protocol

Parameters	Values
Simulation Area	951m * 100m
Number of Nodes	17
Node initial Energy	10 Joule
Packet Size	512 bytes
Traffic Type	CBR (UDP)
The propagation Model	TwoRayGround
Simulation Time	50 Seconds

We have used packet size of 512 bytes which starts sending packets at around 0.1 sec. The initial energy of node is 10 joule. We have used UDP traffic as underlying transport protocols. During simulation UDP data traffic is sent in bytes/sec. We attach the CBR (Constant Bit Rate) application that generates constant packets through the UDP connection.

G. Evaluation of results

Figure 8 shows the simulation of direct diffusion transmission. In this figure node 0 is act as base station and remaining nodes assist in routing of the packets and have their own purpose. In this figure each nodes send their data directly to the base station. So energy consumption is more. As energy is limited source in wireless sensor network, this energy should be used in efficient way. We have implemented another protocol to overcome the drawback of this existing direct diffusion transmission.

Figure 9 shows the simulation of LEACH Protocol. In this node0 is the BS and node1 is the Cluster Head (CH). Node1 collect all the data from node 2, node3, node4, node5, node6, node7, node8, node9, node10 which are members of the cluster represented be CH and transmit the data to the base station through single hop.

Figure 10 shows the simulation of LEACH with TREE protocol. In this figure node7 is the root node of the TREE which transmits the data to cluster head node1. Node1 then sends the data to base station. Figure 11 shows the simulation of Novel1 protocol. In this figure nide1 is the original cluster head and node2 is associate cluster head. In this the energy of cluster head reaches to minimum level so now node2 takes place as CH. So all the nodes will send their data to node2. In figure node4 and node6 sends their data to node2 and node2 then sends the data to base station node that is node0.

Figure 12 shows the simulation of TRREPSI Protocol. In this figure there are two clusters. One cluster is represented by node7 as cluster head and other cluster is represented by node1 as a cluster head. The data collected by node7 is transmitted to node1, node1 aggregate the data and finally it sends to the base station node that is node0. Figure 13 shows the simulation of Novel2 protocol. In this figure there is associate cluster head which is represented by node2. The node2 collects the data from each cluster heads and finally send to base station.

Figure 14 shows the simulation results generated. In this figure performance of all energy efficient strategies is shown. From figure 14 we can see that the performance of our proposed protocols is better than existing protocols. As shown in figure 14 Novel2 protocol has less energy consumption of nodes than Direct Diffusion, LEACH, LEACH with TREE, Novel1 and TREEPSI Protocol. Based upon the simulation results Novel2 can control the residual node energy a d effectively extend the network lifetime without performance degradation.

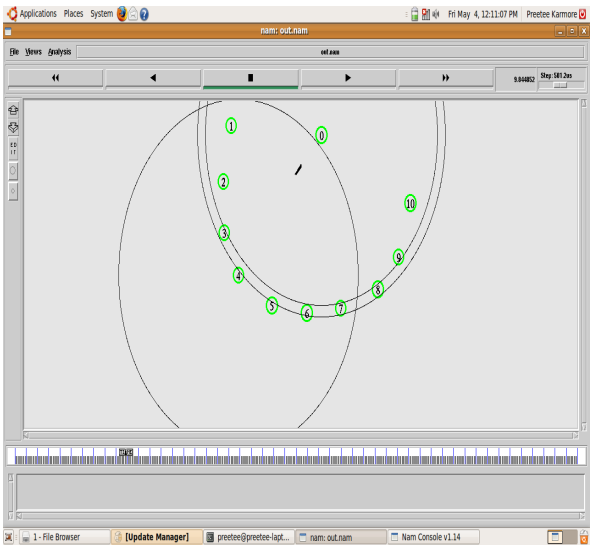

Fig.8. Direct Diffusion Transmission

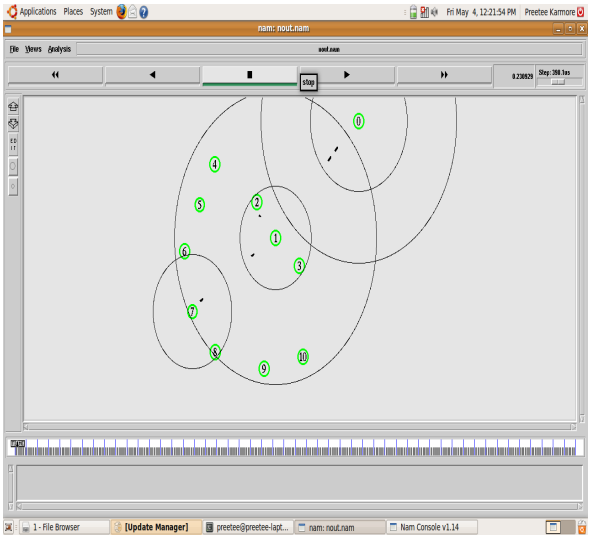

Fig.9. LEACH Protocol

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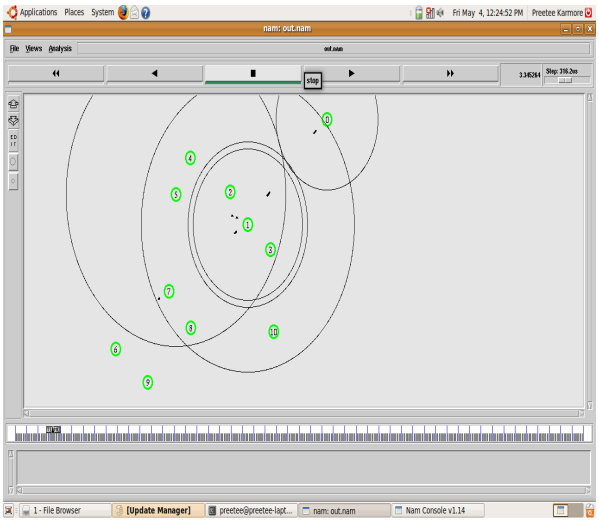

Fig.10. LEACH with TREE Protocol

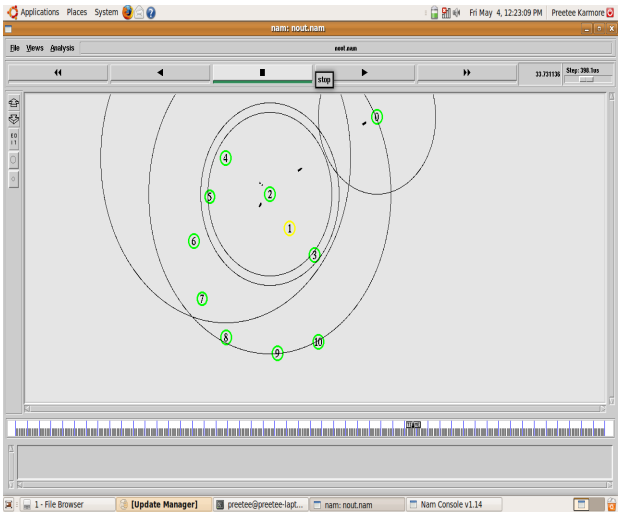

Fig.11. Novel1 Protocol

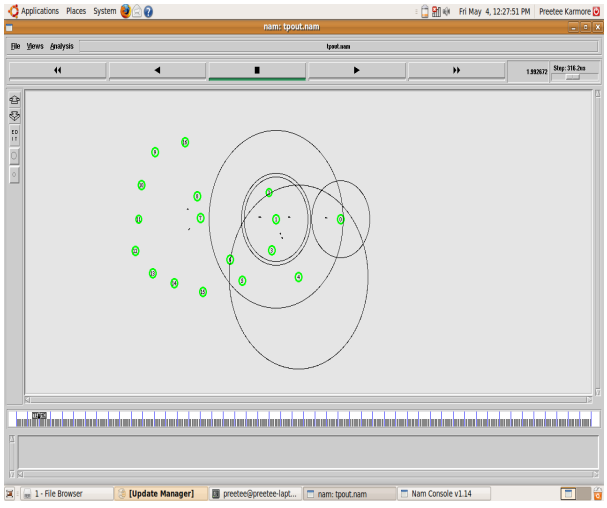

Fig.12. TREEPSI Protocol

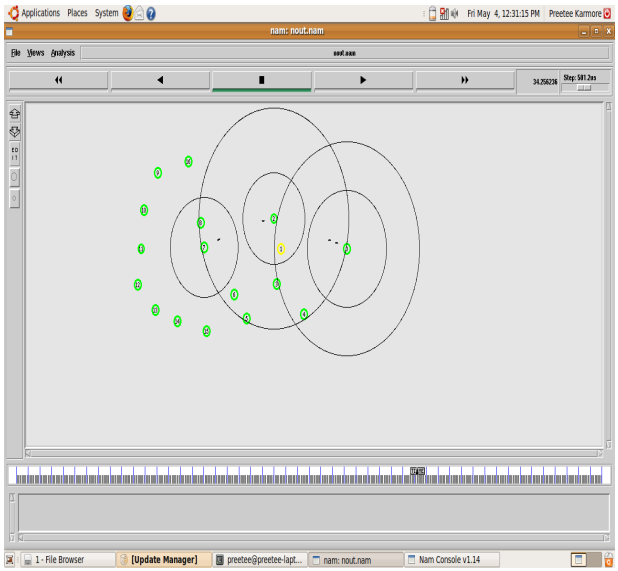

Fig.13. Novel2 Protocol

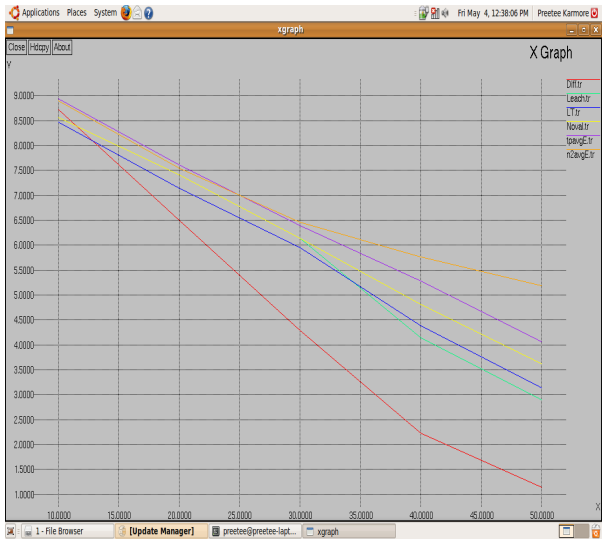

Fig.14. Performance Comparison Graph

V. CONCLUSION

In sensor networks, the most notable problem is limited battery energy. If any one of the node dies due to battery outage, the whole system dies. Therefore, efficiently utilizing the available resource is one of the primary concerns in sensor networks. Energy efficiency is the most important design consideration for wireless sensor networks and its optimum utilization is a challenge in its own regard.

By this notion, we proposed novel protocols in comparison to existing one. Through simulation result we can conclude that Novel1 protocol is better than LEACH and Novel2 protocol is better than TREEPSI protocol in term of energy consumption.

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